

AFRL-VA-WP-TP-2003-327

**VALIDATION AND VERIFICATION OF
INTELLIGENT AND ADAPTIVE
CONTROL SYSTEMS (VVIACS)**



James Buffington

SEPTEMBER 2003

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Validation and Verification of Intelligent and Adaptive Control Systems (VVIACS)

***James Buffington
September 17, 2003***

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OUTLINE



- INTRODUCTION
- APPROACH
- STATUS
- Q&A



TEAM



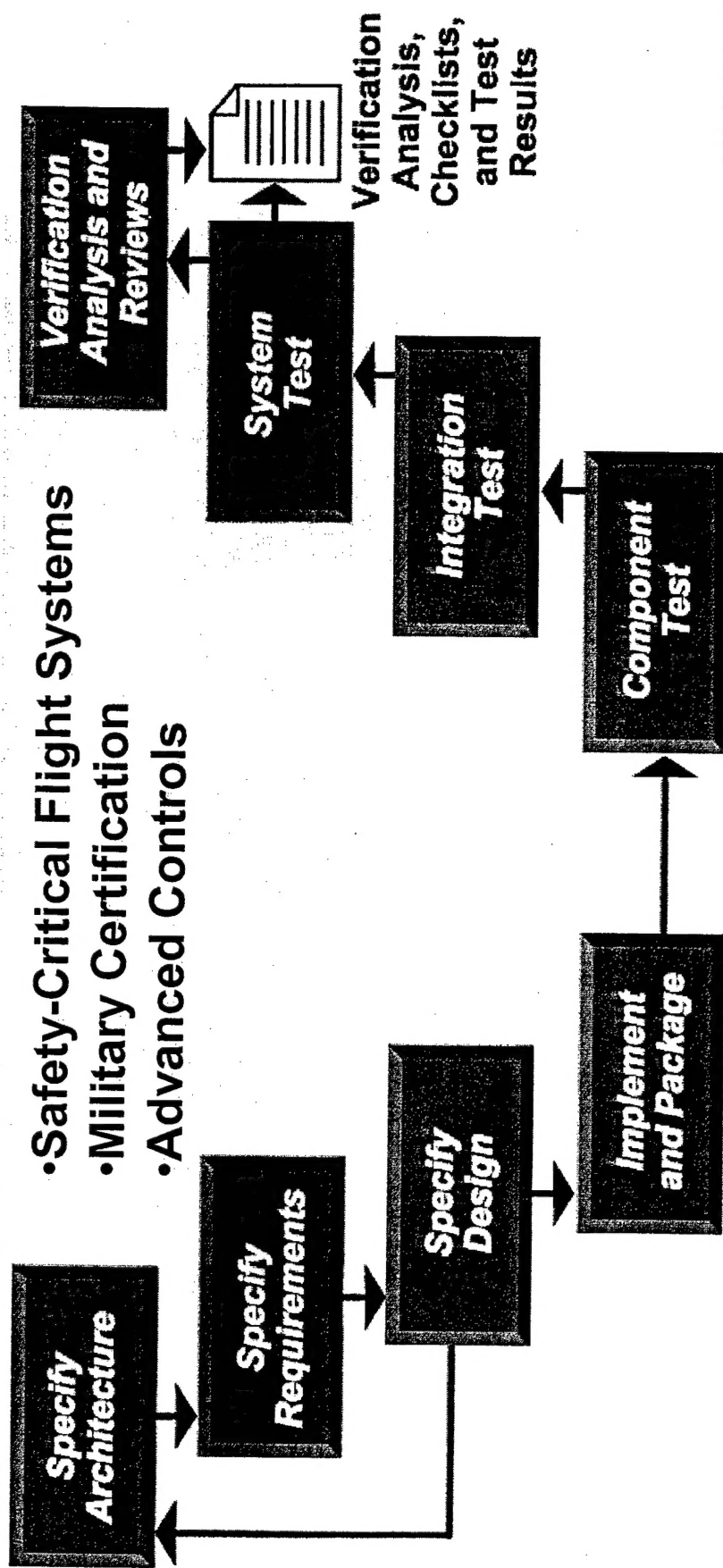
Team Member (Expertise)	VIACS Assessment	VIACS Development	VIACS Evaluation
	LM (Flight Certification)		
	SSCI (Autonomous Control)		
	GEGR (V&V)		
	Prof. Krogh (V&V)		
Participation Level			
	<div></div> High	<div></div> Moderate	<div></div> Low

A02-04851038

Vince Crum – AFRL - Government PM
Jim Buffington – LM Aero - Contractor PM
Clinton Plaisted – LM M&FC
Prasanta Bose – LM M&S
Bruce Krogh – Carnegie Mellon University
Tim Johnson – General Electric Global Research
Ravi Prasanth – Scientific Systems Company, Inc
Peter Stanfill – LM Aero
Greg Tallant – LM Aero
Barry Frazier – LM M&FC
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SCOPE



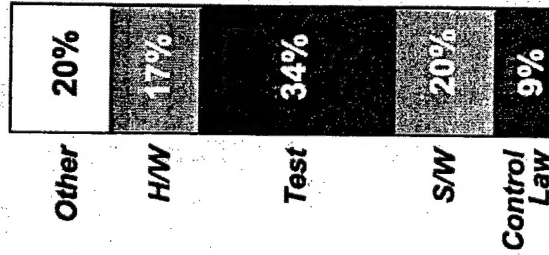
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MOTIVATION

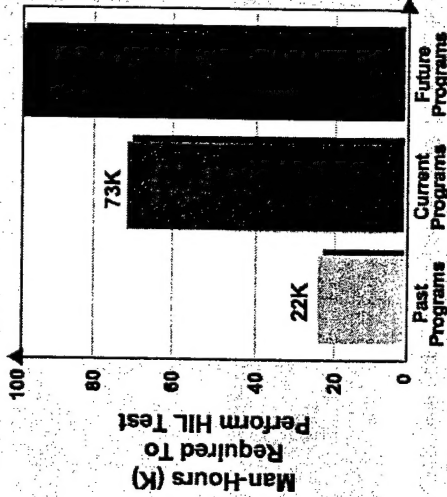


Costs of Design and Testing Dominate Current Flight-Safety-Critical Systems

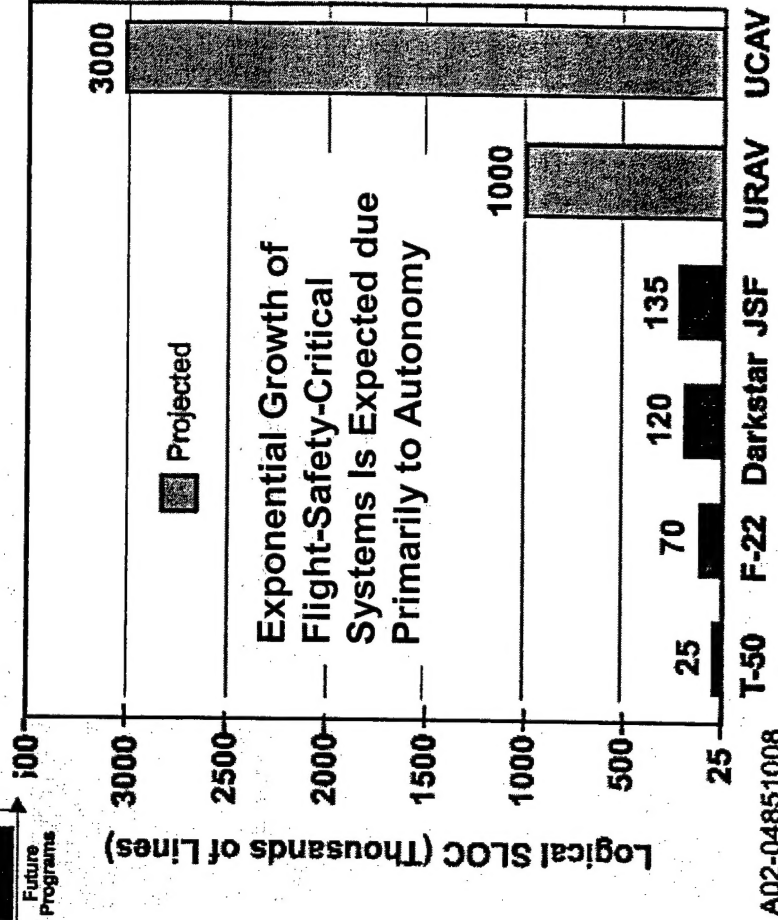


Typical Flight Critical System Development Cost Model

A02-04851004



Future Military Program Testing Hours Are Forecast to Triple



Exponential Growth of Flight-Safety-Critical Systems Is Expected due Primarily to Autonomy

A02-04851008



PURPOSE



GOAL:

Enable affordable development of future safety-critical flight systems with prescribed levels of safety and reliability.

OBJECTIVE:

Study, develop, and demonstrate effective V&V technologies for advanced safety-critical control system flight certification.

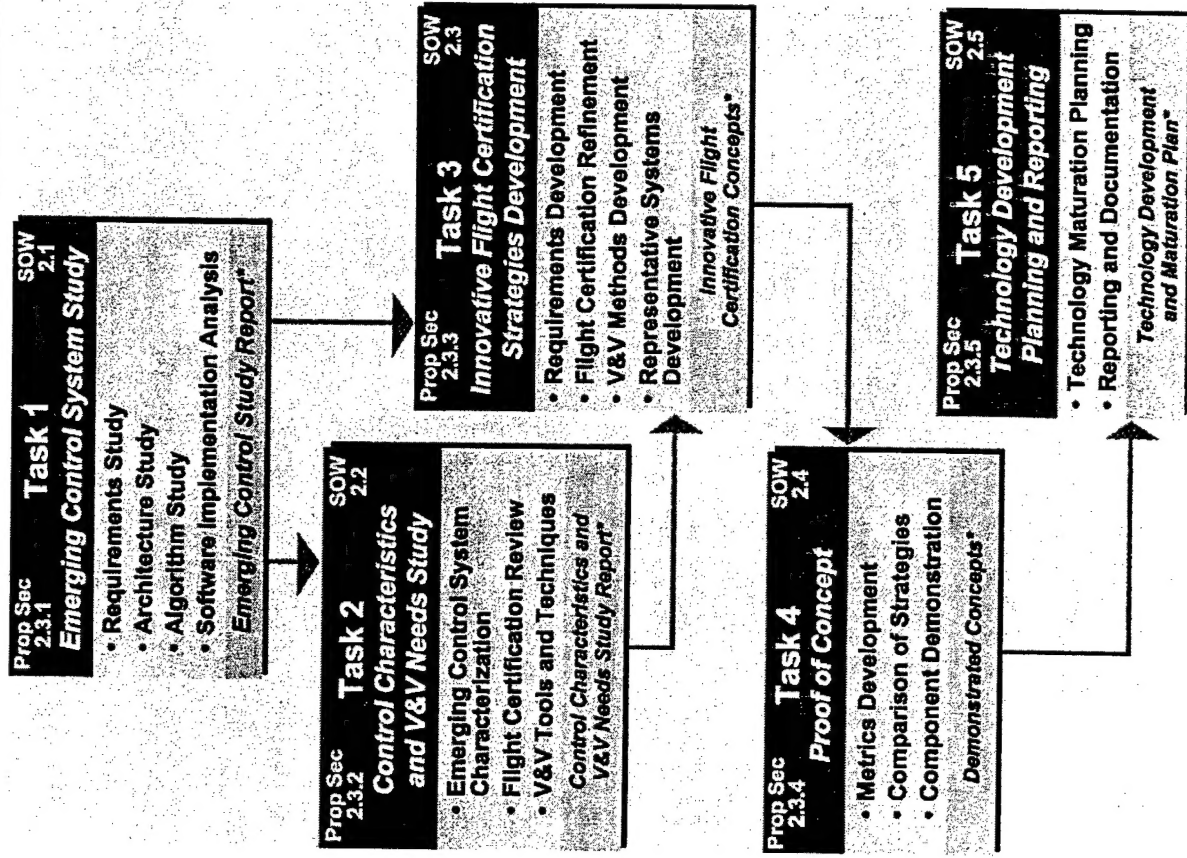
- Classify emerging safety-critical control systems according to fundamental attributes*
- Develop and demonstrate preliminary V&V strategies that focus on critical flight certification schedule and cost points*
- Identify high-payoff V&V process, tool, and method technologies for further development*

APPROACH:

- Use Extensive Experience Base and Diverse Team to Develop Innovative Concepts*
- Evaluate Concepts in Realistic Framework to Maximize Transition Success*



TASKS





ASSESSMENT

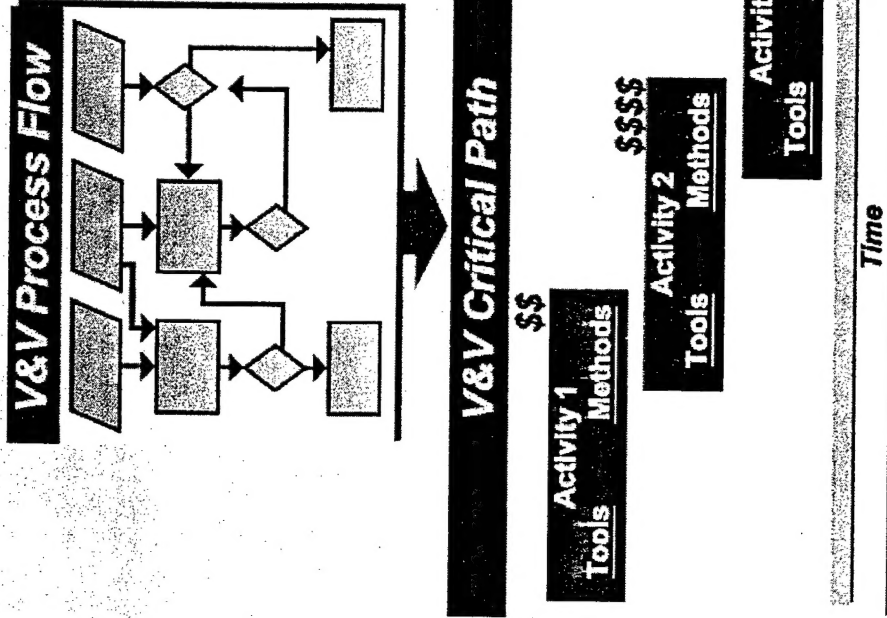


- Emerging Control System Study
- Control System Characterization

Control System	Functional/Architectural Attributes									
	Adaptive	Learning	Decision Making	Predictive	Cooperative	Optimization	Reasoning	Integrated	Distributed	TBD
	RESTORE	SCARF	CAUS	ITAC	ADGAS	Auto ACAS	Intelligent Control	AAAB	SEC	REACT
	✓		✓		✓	✓	✓	✓	✓	✓
Fundamental Properties										
Functional/Architectural Attributes	Non-Determinism					Non-Stationary				
	Adaptive	Learning	Predictive	Cooperative	Optimization	Reasoning	Integrated	Distributed	TBD	TBD
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Flight Certification/V&V Needs, Deficiencies										
Fundamental Properties	Non-Determinism					Non-Stationary				
	Adaptive	Learning	Predictive	Cooperative	Optimization	Reasoning	Integrated	Distributed	TBD	TBD
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

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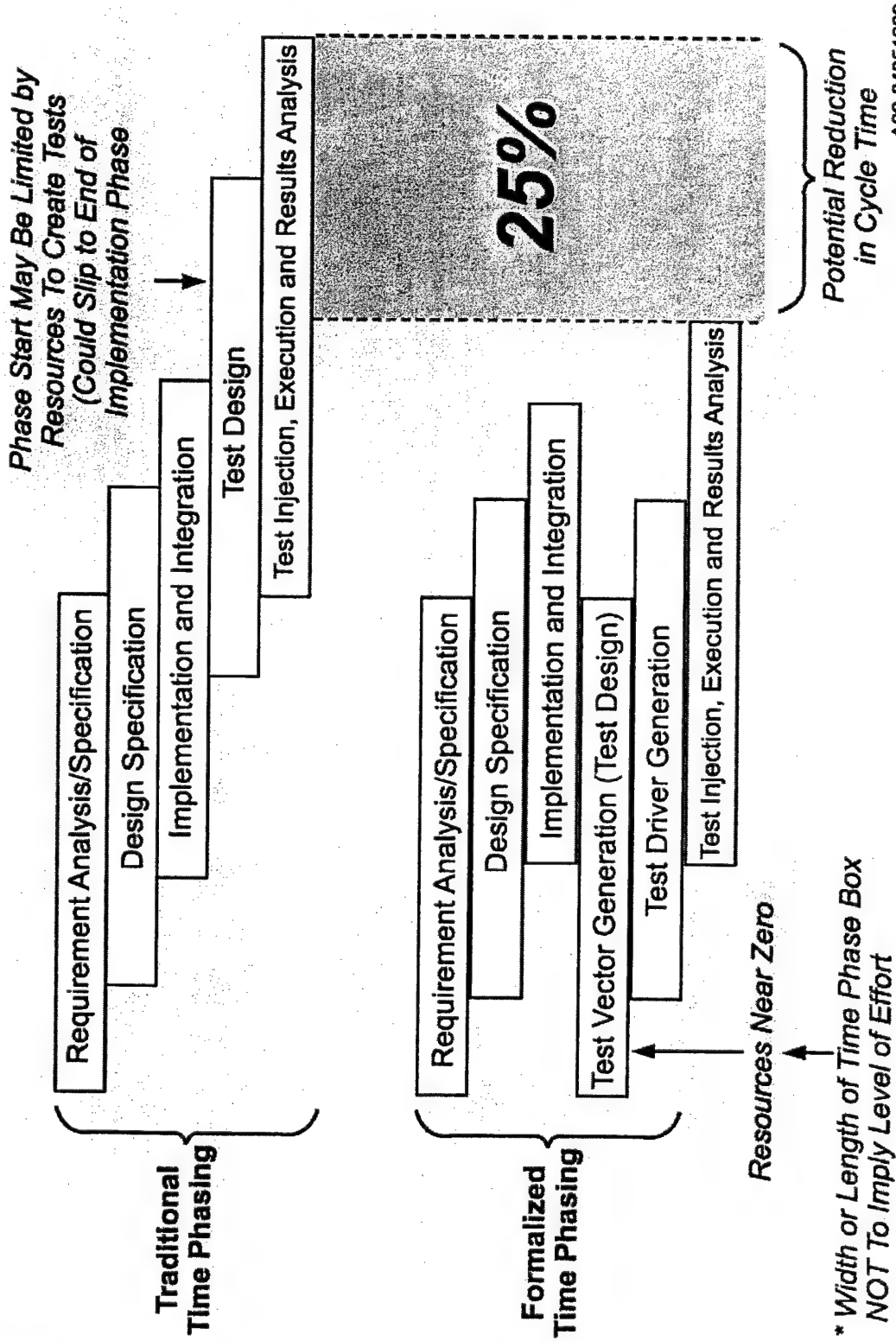
- V&V Needs Study



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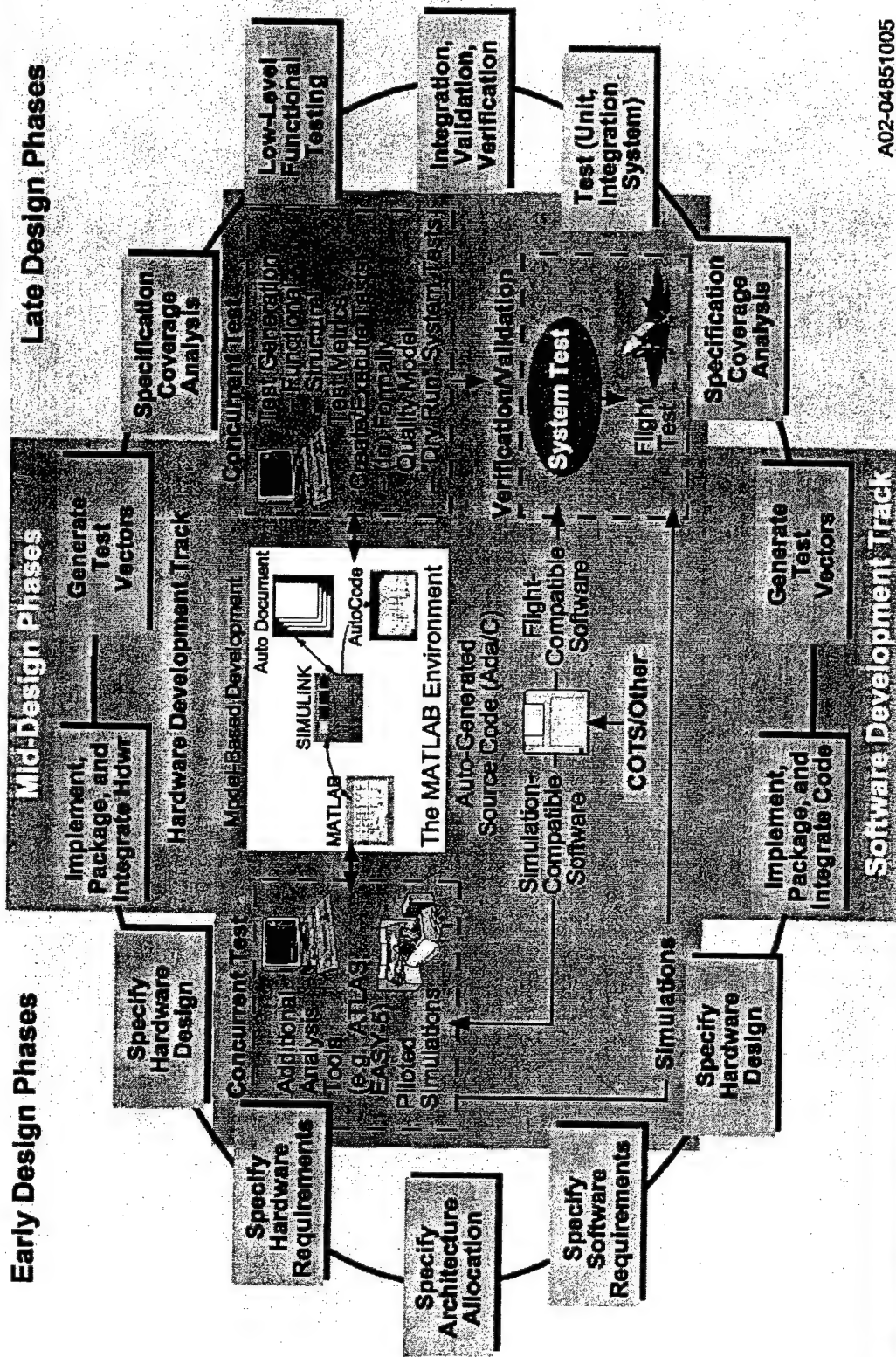
DEVELOPMENT - Processes



•Process Models



DEVELOPMENT - Methods





EVALUATION - Proof of Concept



Metric Definition

- Flight Safety
- S/W Dev Cost
- LCC
- Fit Cert Cost
- Fit Cert Effort
- Others TBD

Assessment

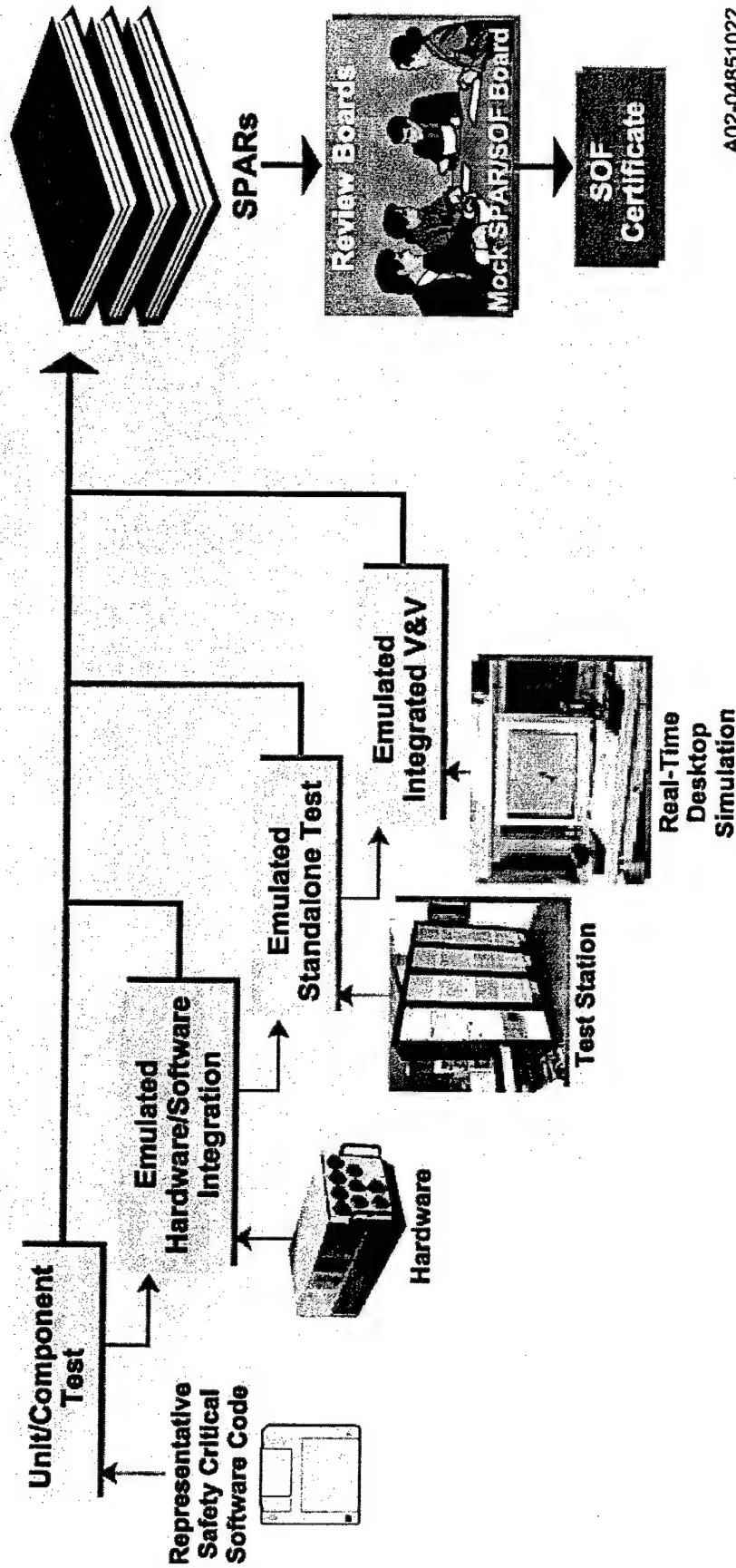
Innovative Flight Certification Concept	V&V Category	Current TRL	C _{DEV} ROM S/W Dev Cost (\$M)	ROM Certification Cost (\$M)	Transition Metrics		Performance Metrics								Cost-Benefit Metrics		R _T Technical Risk	Score	Rank
					Current Systems	Next-Generation Systems	Feasibility	Flight Safety	Resource Utilization	Software Defect Density	Test Coverage	Design Cycle Time	Touch Labor Reduction	Product Size	Cost	Benefit	CBR		
Concept A	Proc, Tool	5	5	7.5	100	15	100	25	100	25	100	100	100	100	0.045	0.775	0.098	0.187	1
Concept B	Tool Meth	6	6	9	100	15	100	25	100	100	100	100	100	100	0.054	0.943	0.069	0.187	2
Concept C	Meth	5	12	38	100	15	100	25	100	100	100	100	100	100	0.107	0.813	0.117	0.187	3
Concept D	Tool	4	6	9	100	0	100	100	100	100	100	100	100	100	0.081	0.981	0.081	0.333	4
Concept E	Tool	6	1	1.5	0	0	25	25	75	25	25	75	25	100	0.012	0.338	0.008	0.187	5
Concept F	Proc	4	8	12	100	0	75	100	100	100	100	100	100	100	0.081	0.813	0.1	0.333	6
Concept G	Proc	5	120	180	100	15	100	25	100	100	100	100	100	100	1.071	0.813	1.173	0.187	7
Concept H	Proc, Meth	3	63	7.56	100	0	100	25	100	100	100	100	100	100	0.054	0.825	0.065	0.5	8
Concept I	Proc, Tool, Meth	3.5	36	84	100	7.5	100	25	25	25	25	100	100	100	0.26	0.9	0.427	0.187	9
Concept J	Proc, Tool, Meth	3	25	37.5	100	0	100	100	100	100	100	100	100	100	0.253	0.889	0.286	0.5	10

Most Promising Concepts for Demonstration

A02-04851045



EVALUATION – Safety of Flight Certification Model

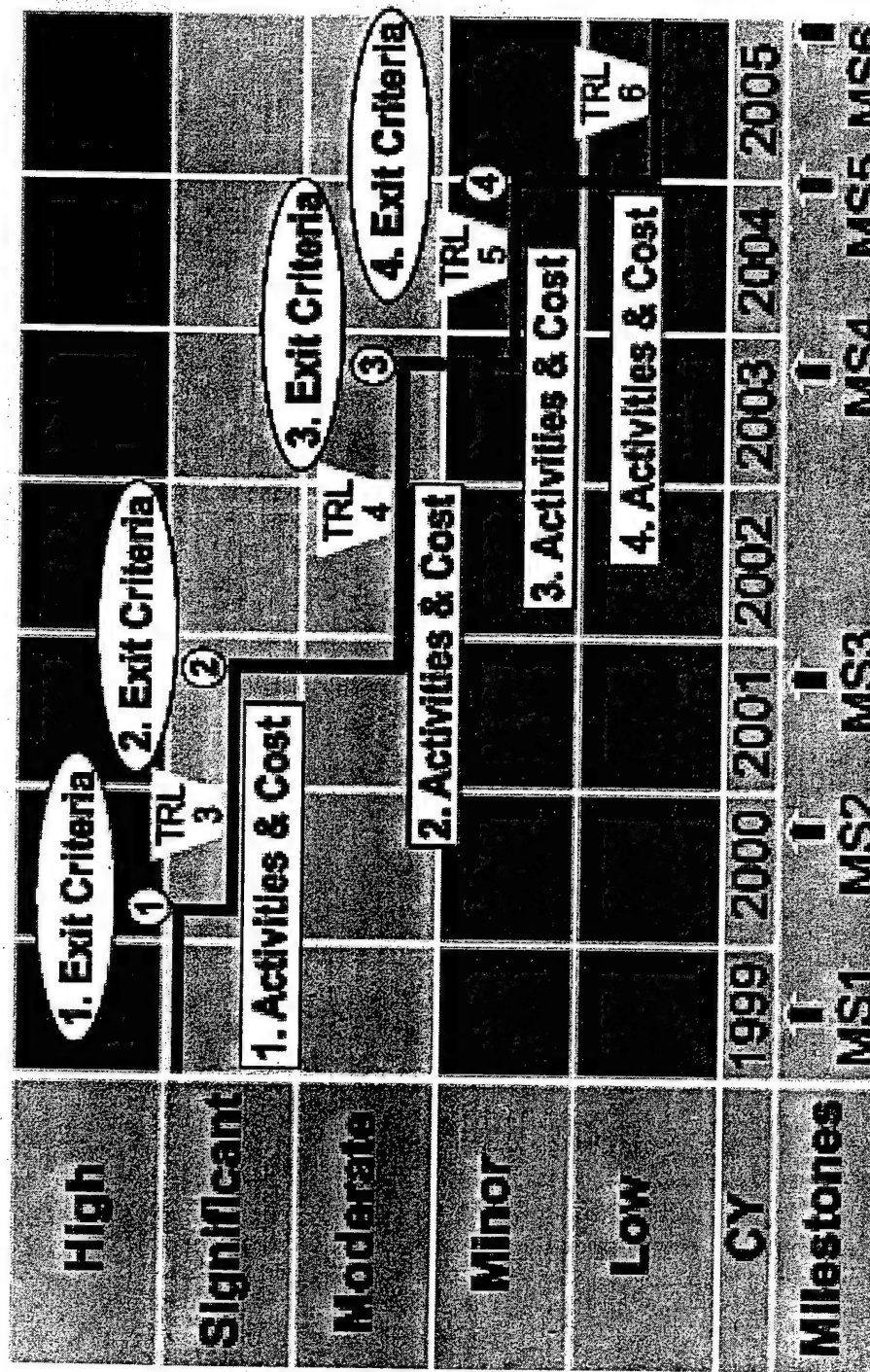


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EVALUATION - Planning

Tech Risk Level



A02-04851020



STATUS – Program Schedule



3Q CY02 4QCY02 1QCY03 2QCY03 3QCY03 4QCY03 1QCY04 2QCY04 3QCY04 4QCY04

Task 1 – 100% complete

Task 2 – 85% complete

Task 3 – 0% complete

Task 4 – 0% complete

Task 5 – 0% complete

Reviews / TIMs





STATUS - Database Tool



Microsoft Access - [Main Menu: Form]

File Edit View Insert Format Records Tools Window Help

Type a question for help

LOCKHEED MARTIN

LOCKHEED MARTIN

Validation & Verification of Intelligent and Adaptive Control Systems

TECHNICAL

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GLOSSARY

Task 1 - Emerging Control Systems Study

Task 2 - Control Characterization and VV Needs

Out Access

Record: 14 of 1

Form View

NLM



STATUS - Control System Database



Task 1 Database

Microsoft Access - [Temp] Type a question for help

File Edit View Insert Format Records Tools Window Help

9 B I U A L E

Main Menu Project Downselect

CATEGORY	DATA FIELDS	INSTRUCTIONS	REFERENCE MATERIAL
Program Name	AFTACSIAGCNS	Enter distinct name of program or project	
Application	Military Aircraft	Choose best selection from menu	
Time	Past	Past, Current, Planned, or Future Program	
Technology Readiness Level	7	Choose best selection from menu	TRL chart
Maturity	Prototype	Choose best selection from menu	
Information Source	Mechanization / Implementation	Level of documentation available for further study	
Releasability of Information	ITAR	Choose best selection from menu	
Emerging Control Level	Medium	Choose best selection from menu	ECL chart
Primary Approach/Attribute	Classical	Enter a few key words that describe the basis of the approach and support the Emerging Control Level	
Control Domain	Guidance	Choose best selection from menu	Control Domain chart
Autonomous Control Level	1	Choose best selection from menu	ACL spreadsheet
System State	Hybrid	Choose best selection from menu	System State chart
VIIACS Owner	LM Aero	Choose best selection from menu	
Developer	LM Aero	Enter the prime contractor of the program	
Key Words		Enter a few key words for the project	
Comments		Enter any additional comments	

Record: 14 of 40 Form View

Primary
Scoring
Factors

Other Factors:
Maturity
Developer
Autonomy
Application



STATUS – Emerging Control Systems



ECS PROJECT

AIMSAFE / RESTORE

ICARUS

LOCAAS

Enhanced GNC Algorithms

XACT

Software Enabled Control

EDCS F-16 Autopilot

Engine Control Cutoff Mode

Intelligent Engine Control

Intelligent Maintenance Advisor for Turbine Engines

Formation Flying Spacecraft

DESCRIPTION

Integrated Management, Adaptive Control

Intelligent Autonomy

Autonomous Control

Dynamic Programming Optimization

Adaptive Failure Management

Optimal Trajectory Generation

Outer Loop Hybrid Control

Nonlinear Hybrid Control

Intelligent Failure Management

Model-based Health Management

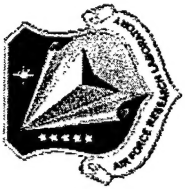
Multi-vehicle Control



STATUS - Summary



- **Emerging Control System Study (Task 1)**
 - Completed study and organization of project data (48 projects)
 - Completed project data collection and insertion into database tool
 - Completed project data down-select to 10 Emerging Control Systems
 - Developed preliminary project glossary
- **Control Characterization and V&V Needs Study (Task 2)**
 - Developed detailed task plan
 - Review of LM Aero FC/VMS development processes and program plans
 - Developed preliminary representative time-phased critical-path representation of development process
 - Completed Control Characterization of control system projects with emphasis on Emerging Control Systems



Q&A



Questions?

